Historic, archived document

Do not assume content reflects current
scientific knowledge, policies, or practices.

A99.9
F764U copy 4

United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

Research Paper
INT-329

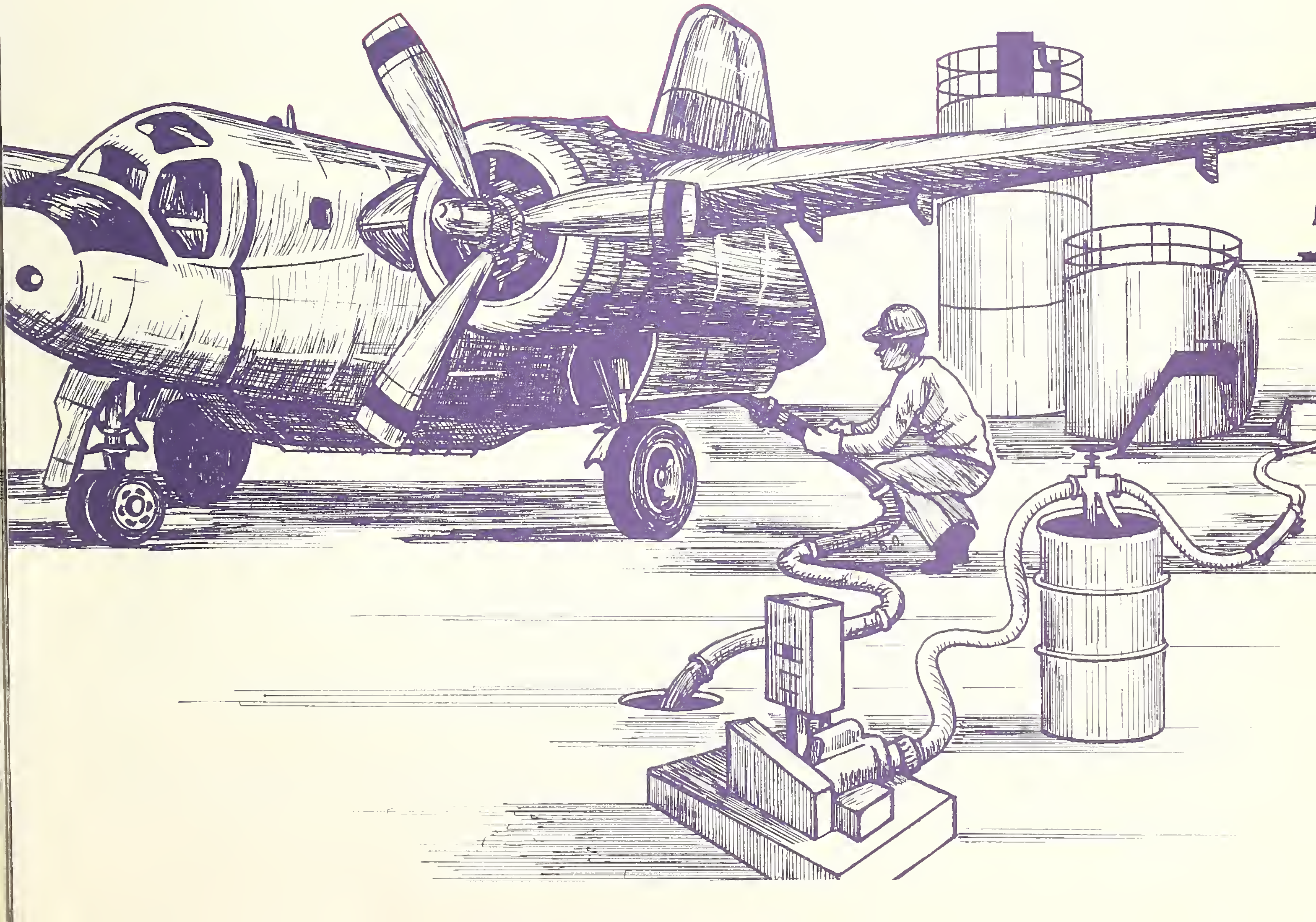
May 1984

Corrosivity of Short-Term Forest Fire Retardants

U.S. DEPT. OF AGRICULTURE

**Charles W. George
Cecilia W. Johnson**

EXTRA COPY



THE AUTHORS

CHARLES W. GEORGE graduated from the University of Montana in 1964 in forest engineering. He received his M.S. degree from the University of Montana in 1969. In 1965 he joined the Intermountain Station's Northern Forest Fire Laboratory staff in Missoula, Mont., where he has conducted studies related to prescribed fire, pyrolysis and combustion, and fire retardant delivery systems. He is currently the leader of the Fire Control Technology Research Work Unit.

CECILIA W. JOHNSON, a chemist in the Fire Control Technology Research Work Unit at the Northern Forest Fire Laboratory, received a degree in chemistry and mathematics from Whitworth College in 1968. She attended graduate school in chemistry at the University of Montana prior to joining the Laboratory in 1971. She works in fire retardant research.

RESEARCH SUMMARY

The corrosivity of several short-term fire retardants was determined by conducting 90-day uniform corrosion tests, determining uniform corrosion rates, and microscopically examining exposed coupons for occurrence of intergranular corrosion. Aluminum, brass, steel, and magnesium alloys were exposed under total and partial immersion conditions at 70° and 120° F. The susceptibility of aluminum 2024-T3 and magnesium Az–31-B to intergranular corrosion was determined when acceptable uniform corrosion rates were obtained. Results indicate that in terms of uniform corrosion, short-term retardants are generally less corrosive than present long-term retardants. Nevertheless, the frequency of intergranular corrosion warrants an effort to identify and add corrosion inhibitors to short-term retardants. Two short-term retardants were recommended without modification for use from fixed-wing aircraft. Because all short-term retardants caused intergranular corrosion on magnesium, it is recommended that they not be applied from helicopters with fixed tanks.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Corrosivity of Short-Term Forest Fire Retardants

Charles W. George
Cecilia W. Johnson

INTRODUCTION

The increasing costs of long-term, salt-containing forest fire retardants have stimulated renewed interest in the use of thickened water or short-term retardant solutions. Unlike long-term retardants, short-term retardants do not contain a combustion-inhibiting chemical that is effective after the water has evaporated. Thus, short-term retardants are effective only as long as they retain adequate moisture.

Short-term retardants range from equally as effective as long-term retardants to infinitely less effective, depending on the conditions and tactical objectives of use. For example, the active salt in long-term retardants is of minimal value when the retardant is applied directly to the fire (direct attack), to knock down or cool the fire in support of ground personnel. When the retardant is to be applied 30 minutes or more before the fire will reach the treated fuel (indirect attack), sufficient moisture may have evaporated so that without a combustion-inhibiting chemical, little or no value is obtained. Thus, for application in relatively close proximity (time or distance) to the fire's edge, short-term retardants may well be as effective as long-term retardants.

Much attention has been given to the corrosivity of the salts in long-term retardants and their effects on aircraft structure, maintenance, and safety.

Damage to aircraft and retardant-mixing equipment has been evaluated on several occasions (Davis and Phillips 1965; Gehring 1974). Numerous laboratory studies have been conducted to determine the corrosivity of retardants to alloys commonly exposed, the effects of exposure, retardant properties, inhibitor systems, water quality, and other variables (USDA Forest Service 1964; Bradford 1973, 1974; Gehring 1974, 1978, 1980). Results of these studies and studies conducted at the Northern Forest Fire Laboratory[1] were considered in developing test procedures and establishing Forest Service requirements for long-term fire retardants. The requirements are based on the use for which the retardant system was developed (fixed-wing aircraft, helicopter, ground application) and the mixing, handling, use, and other factors (i.e., the need for the aircraft to sit loaded). The established corrosion requirements for long-term retardants are given in Forest Service specifications (USDA Forest Service 1982), and are summarized in table 1.

Because short-term retardants are usually thought of as relatively inert water-thickening agents, there has not been much concern about corrosivity. In the early development and use of retardants in the mid- 50's and early 60's, however, it was found that some short-term retardants, such as Algin-gel, were severely corrosive (Davis and Phillips 1965).

Although specifications for short-term retardants have not been established, the use and exposure of aircraft, mixing, storage, and handling equipment is often similar to that of long-term retardants; therefore, the same corrosion requirements may be applicable.

The present study was conducted to determine the corrosiveness of short-term fire retardants and to compare their performance under established long-term fire retardant corrosion test procedures to existing standards. The results of the corrosion testing of present short-term retardant formulations will be used to determine whether their characteristics warrant development of qualification procedures or criteria different from or supplemental to those applied to long-term retardants.

STUDY DESCRIPTION

The study consisted of a series of tests to quantify the uniform corrosion rate and intergranular corrosion susceptibility of selected alloys exposed to various short-term retardant formulations. Uniform corrosion is corrosion spread evenly over large areas of the exposed surfaces. The amount of damage caused by the attack is ordinarily determined by comparing the thickness of the corroded metal with that of an undamaged specimen. (The corrosion rate is expressed as the thickness of metal removed as a function of time, usually thousandths of an inch [mils] per year [mpy].) Intergranular corrosion occurs at the boundaries of the metal grains, first consuming the material between the grains and then attacking the grains themselves. Intergranular corrosion, like pitting, causes a loss of strength and ductility disproportionate to the amount of metal destroyed.

The specific alloys used are identified in table 1 and were a result of previous field and laboratory studies, including an assessment of the existing fire retardant-caused corrosion problem.

The uniform corrosion rates were determined using standard weight-loss methods in which coupons of the specific alloys were exposed to the short-term retardants under a variety of conditions (total immersion, partial immersion, and 70° F and 120° F solution

---

[1] Laboratory studies conducted at the Northern Forest Fire Laboratory under study plan 2107-75-500, George, C. W. and Johnson, C. W., "Laboratory investigation of fire retardant-caused corrosion" and results on file.

Table 1.—Corrosion requirements for forest fire retardants (USDA Forest Service specifications)[1]

	2024-T3 aluminum				4130 steel				Yellow brass				Az-31-B magnesium			
	70° Total	70° Partial	120° Total	120° Partial	70° Total	70° Partial	120° Total	120° Partial	70° Total	70° Partial	120° Total	120° Partial	70° Total	70° Partial	120° Total	120° Partial
Premix components																
Liquid components and concentrates	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	[2]5.0	[2]5.0	[2]5.0	[2]5.0
Mixed retardants																
Fixed-wing or helicopter with bucket	[3]2.0	[3]2.0	[3]2.0	[3]2.0	2.0	5.0	2.0	5.0	2.0	5.0	2.0	5.0	[4]—	[4]—	[4]—	[4]—
Helicopter with internal or fixed tank	[3]2.0	[3]2.0	[3]2.0	[3]2.0	2.0	5.0	2.0	5.0	2.0	5.0	2.0	5.0	[3]2.0	[3]2.0	[3]2.0	[3]2.0
Ground application	2.0	2.0	2.0	2.0	2.0	5.0	2.0	5.0	2.0	5.0	2.0	5.0	[4]—	[4]—	[4]—	[4]—

[1] All corrosion rates will be determined by 90-day weight loss. All uniform corrosion rates are the maximum allowable average of at least three replicates. In addition, the standard error of the mean shall not exceed 0.5 for total immersion or 1.0 for partial immersion. (The number of replications may be increased to decrease the standard error if all values are retained to calculate the average and the standard error.)

$$s_m = \sqrt{\frac{X_i^2 - n\bar{X}^2}{n^2}}$$

[2] If submitted for "helicopter with internal or fixed tank"; for all other types, refer to footnote 4.
[3] Intergranular corrosion tests will be performed; no intergranular corrosion is allowed.
[4] Test shall be conducted for performance information.

temperatures), and the loss of weight of the coupons determined. After weight-loss determinations were completed, the coupons were sliced, mounted, polished, and etched using standard metallurgical techniques, and examined microscopically for intergranular corrosion.

The short-term retardants were selected either from those currently being used or those being evaluated in the field by fire management agencies. The concentrations or mixing ratios to be used in the study were similarly selected. Two retardants—Gelgard® and Tenogum® —were also included because of their previous history of use in Alaska and Canada with water-scooping aircraft such as the CL-215 and PBY (the short-term retardant being injected during the water-skimming operation). Table 2 lists the retardants included in the study, the concentration or mixing ratio, and the manufacturers or distributors.

METHODS

Methods used to determine corrosive characteristics of short-term fire retardants were similar to those developed for long-term fire retardants and adopted in Forest Service specifications (USDA 1982). The procedure calls for total and partial immersion of separate coupons of aluminum, steel, brass, and magnesium in freshly prepared retardant samples for 90 days at temperatures of 70° ± 5° F (21.1° ± 2.8° C) and 120° ± 5° F (48.9° ± 2.8° C). Test procedures for long-term retardants include three replications (coupons) for each immersion condition (total and partial) and temperature, and each of the four alloys. These replications are required because of the high corrosion rates and the poor

Table 2.—Short-term fire retardants selected for the study

Short-term retardant	Concentration or mixing ratio
	Percent by weight
Absorbex 2020 SLS Absorbent Polymers, Inc.	0.66 and 0.75
Short-Stop (SGP502S) Merryhill Co. (Henkel Corporation starch)	0.75 and 1.0
Fire-Trol ST-poly, Poly-Trol Chemonics Industries (Nalco Chemical Co. synthetic polymer)	0.66 and 1.5
Fire-Kill I Sanitek Products, Inc. (Kelco Xanthan gum)	1.0
Fire-Kill II Sanitek Products, Inc. (Xanthan gum and synthetic polymer)	0.75 and 1.0
Fire-Trol AC-1 Chemonics (Stein, Hall & Co., Inc. guar gum)	0.50 and 1.0
Gelgard Dow Chemical Co.	0.24
Tenogum Charles Tennant & Co., Ltd.	0.35

reproducibility often accompanying the testing of long-term retardants. Single specimens were used for this study, however, because short-term retardants were expected to exhibit relatively low corrosivity. (Single specimens still required 4 alloys × 2 immersions × 2 temperatures, or 16 corrosion specimens, for each short-term retardant and mixing ratio selected.)

Short-term retardants were designed to be used immediately upon mixing, and hence do not normally contain spoilage inhibitors that facilitate 90-day immersions. Test procedures were therefore modified. The short-term retardant mixture was replaced weekly, to minimize retardant spoilage and degradation.

Test coupons were 1 by 4 by 1/8 inch (2.5 by 10.2 by 0.32 cm), with a small hole at one end for suspending the coupon in the retardant solution. Each coupon was permanently marked, and the length, width, and height measured to 0.001 cm. The coupons were first degreased with an all-purpose cleaner ("409") and then cleaned to remove other foreign substances and remaining oxides using the procedure shown in table 3. Coupons were then rinsed in distilled water, ovendried at 50° to 60° C, and weighed to 0.1 mg. Cleaned coupons were handled with gloves or forceps to prevent contamination. Each coupon was positioned in a 1-quart glass jar containing either 400 or 800 ml of the retardant to be tested. The jars containing 800 ml were used for total immersion exposures, where the coupon was completely immersed. Those containing 400 ml were used for the partial immersion test where exactly 5 cm of the coupon length was immersed. In each case, the coupon was positioned in such a way that it did not touch the side or the bottom of the jar. Each jar was then closed with a tight-fitting lid to prevent evaporation and placed in temperature- controlled incubators. Weekly during the 90-day exposure period the retardant was removed and replaced with fresh retardant. Figure 1 shows two test samples containing coupons, one partially immersed and one totally immersed.

At the end of the 90-day test period, the coupons were removed, rinsed under tap water to remove any remaining retardant, and cleaned using standard cleaning procedures, as presented in table 4. The cleaning procedure given in the table was carefully repeated until films or products of corrosion were removed, being sure not to remove any original alloy. An unexposed control coupon of each of the alloys included in the study was prepared and cleaned in the same manner to determine loss of metal during the cleaning procedure. Following cleaning, all coupons were rinsed in distilled water, air-dried, and weighed to 0.1 mg.

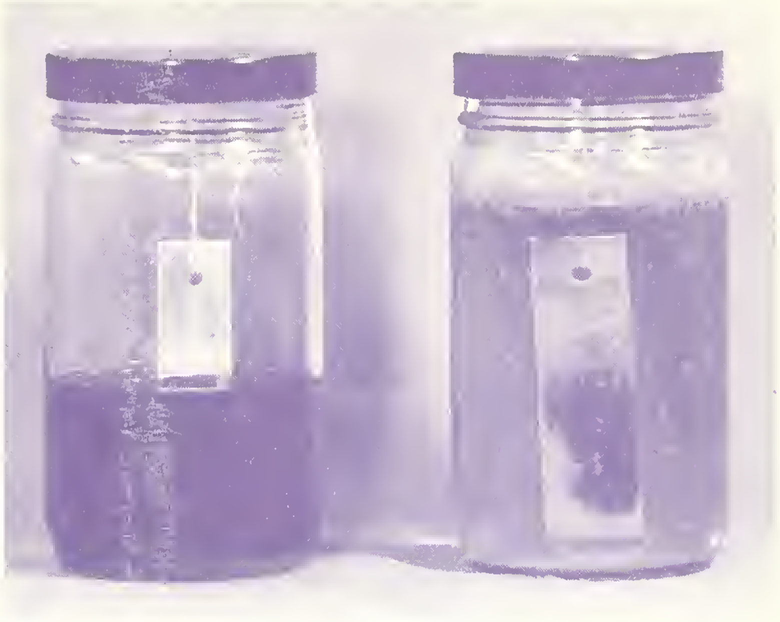


Figure 1.—Corrosion test coupons partially and totally immersed in two short-term retardants.

The corrosion rate in mils per year (mpy) for each coupon was determined using the following equation and values for alloy density:

$$\text{Uniform corrosion rate (mpy)} = \frac{[\text{Initial wt.} - \text{final wt.} - \text{wt.loss by control(mg)}] \times 534}{\text{area(in}^2) \times \text{time(h)} \times \text{alloy density(g/cm}^3)}$$

where the density of:

2024-T3 aluminum = 2.77 gm/cm^3
4130 steel = 7.86 gm/cm^3
yellow brass = 8.47 gm/cm^3
Az-31-B magnesium = 1.77 gm/cm^3

Table 3.—Procedure for cleaning unexposed coupons

Alloy	Chemical	Time	Temperature	Remarks
		Minutes		
Aluminum (2024-T3)	70% HNO_3	2-3	70°F (21°C)	Follow with light scrubbing using non-metalic brush
Yellow brass	20% HCl	2-3	70°F (21°C)	ditto
Steel (4130)	20% HCl	3-5	Cold	ditto
Magnesium (Az-31-B)	19% $Na_2Cr_2O_7$ or 21% $K_2Cr_2O_7$ in dist H_2O	15	Boiling	ditto

Table 4.—Procedure for cleaning exposed corrosion coupons

Alloy	Chemical	Time	Temperature	Remarks
		Minutes		
Aluminum (2024-T3)	70% HNO_3	2-3	70°F (21°C)	Follow with light scrub using nonmetallic brush[1]
Aluminum (2024-T3)	2% $Na_2Cr_2O_7$ in 5% H_3PO_4	10	175°–185°F (79°–85°C)	Use when film resists HNO_3 treatment. Alternate 2 treatments as needed.
Yellow brass	15-20% HCl	2-3	70°F (21°C)	Follow with light scrub using nonmetallic brush[1]
Steel (4130)	5% $SnCl_2 + 2\%\ SbCl_3$ in conc HCl	3-5	Cold	ditto
Magnesium (Az-31-B)	19% $Na_2Cr_2O_7$ or 21% $K_2Cr_2O_7$ in dist H_2O	15	Boiling	ditto

[1] A rubber stopper can be used to scrub coupons with corrosion products which are hard or extremely difficult to remove with a brush.

Figure 2 shows examples of coupons following final cleaning that have been exposed to short-term retardant during the 90-day corrosion test.

When the 90-day uniform corrosion tests were completed and the results scrutinized, selected test coupons were prepared for intergranular corrosion determination. Intergranular corrosion inspections of aluminum and magnesium coupons exposed to the different types of short-term retardants and mixing ratios were made only when uniform corrosion tests indicated that acceptable levels of corrosion were experienced. (Acceptable corrosion levels are shown in table 1.) Intergranular corrosion requirements exist only for aluminum and magnesium alloys because of their use in structural members and other critical components of fixed-wing aircraft and helicopters. (No intergranular corrosion to aluminum coupons is allowed for retardants formulated for fixed-wing aircraft application; no intergranular corrosion to either aluminum or magnesium is allowed for application from helicopters equipped with fixed tanks.)

Standard procedures for determining the occurrence of intergranular corrosion were used in the study. Intergranular corrosion was determined by qualified laboratories under contract (Ocean City Research Corp., Ocean City, N.J.; and Magnaflux Quality Services, Los Angeles, Calif.) Coupons were sliced as shown in figure 3, mounted, polished to 0.3 micron alumina finish, and etched with appropriate reagents using standard metallurgical techniques and examined microscopically up to a magnification of 600 X. If intergranular corrosion was present, its location (the section where it was identified), as well as the depth of intergranular attack and the magnification, were noted. Figure 4 shows a coupon prior to preparation for intergranular examination and specimens that have been prepared for microscopic inspection. Examples of typical intergranular corrosion attack to aluminum and magnesium are illustrated in the photomicrographs in figure 5.

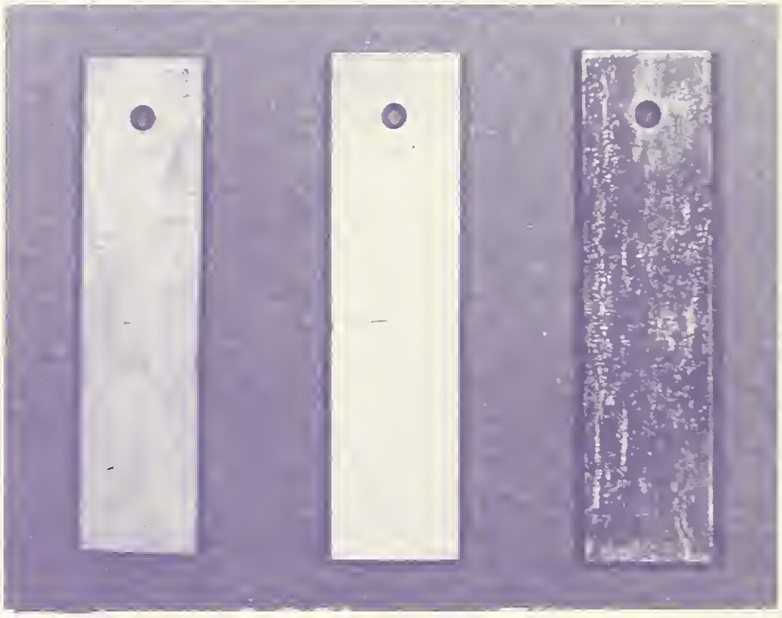


Figure 2.—Examples of exposed corrosion coupons (left coupon aluminum, totally exposed, 2.4 mpy: center coupon aluminum. partially exposed, 4.3 mpy; right coupon, Mg, 10.4 mpy).

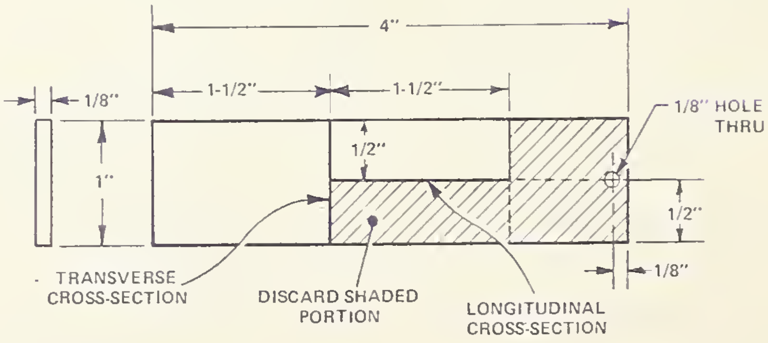


Figure 3.— Diagram of a coupon showing the location of the slice and surfaces to be inspected for intergranular corrosion.

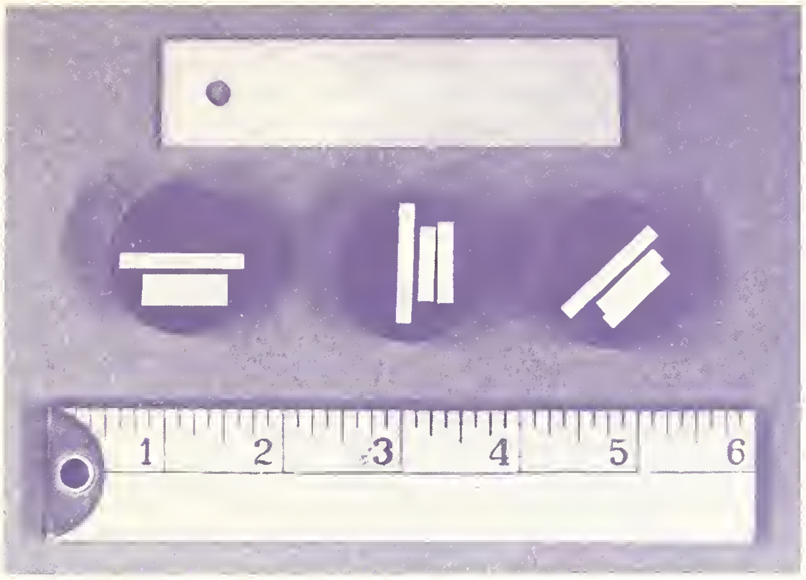


Figure 4.—Coupons which have been cut, mounted, polished, and etched for microscopic examination for intergranular corrosion alongside an unexposed coupon.

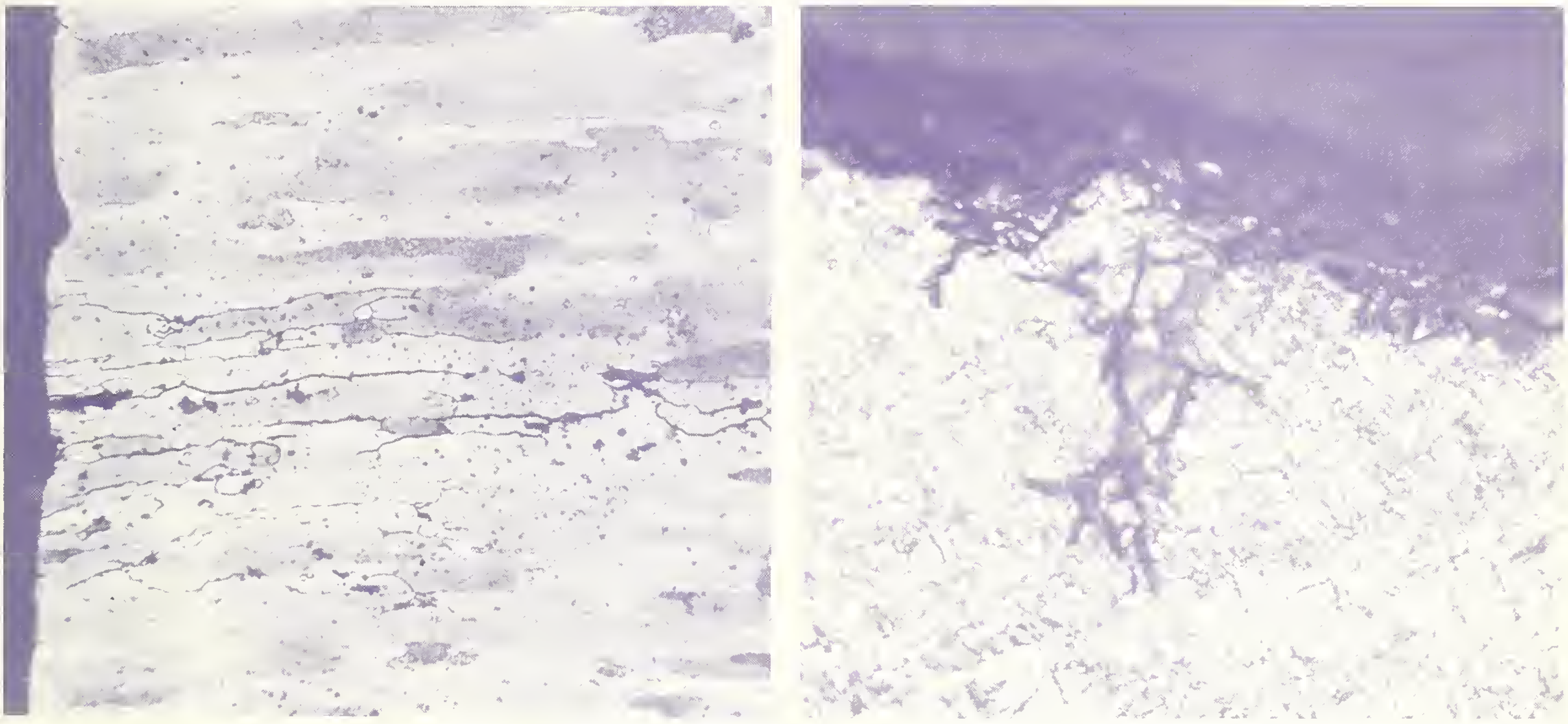


Figure 5.—Photomicrographs of aluminum 2024-T3 exposed to Fire-Trol ST-poly (200 X), left; and magnesium Az-31-B exposed to Fire-Kill II (500 X), right.

RESULTS AND DISCUSSION

The corrosion rates determined for the controls and each of the formulations and concentrations tested are shown in table 5. Note that a single exposure was sometimes used to determine if the concentration or mix ratio of the short-term retardant affected corrosion. Also, a single exposure was used for those short-term retardants having significant use in the past, but which are no longer available or operationally used (Gelgard and Tenogum).

Tests for uniform corrosion indicated that the corrosion rate for short-term retardants is usually much less than the corrosion experienced with long-term fire retardants. Uniform corrosion rates for nearly all exposures to aluminum, steel, and brass alloys were less than 1 mpy compared to the maximum of 2 mpy allowed for long-term retardants (table 1). In all cases, the corrosion rate for magnesium Az-31-B was significantly higher than other alloys. Absorbex 2020-SLS had the highest rate on magnesium (10.3 mpy when totally immersed at 70° F). Both Short-Stop and Fire-Kill II had uniform corrosion rates on magnesium that exceeded the 2.0 mpy requirement established for long-term retardants formulated for application from helicopters equipped with fixed tanks. Corrosion rates on magnesium for these formulations, however, were in the 2 to 3 mpy range and are likely solvable.

An unexpected result was that intergranular corrosion was found on many aluminum and magnesium coupons exposed to short-term retardants. Table 6 provides a summary of those exposures resulting in intergranular corrosion, the location of the corrosion, and the depth of the intergranular attack. (Coupons inspected for intergranular corrosion were identified in table 5.)

The study indicates that although short-term retardants were expected to be less corrosive than long-term retardants, uniform corrosion rates can, as in the case with magnesium exposed to Absorbex 2020-SLS, be unusually high and exceed current allowable levels In addition, some short-term retardants that were relatively noncorrosive to aluminum or magnesium in tests of uniform corrosion exhibited intergranular corrosion which can have a potentially greater impact on the strength of structural members than uniform corrosion Based on these results, the corrosivity of short-term retardants should continue to be an important consideration in selection for operational use. Both long- and short-term retardants should meet similar corrosivity requirements, even though different corrosion-testing procedures may be required.

Absorbex 2020-SLS and Fire-Kill II were the only short-term retardants that met all current corrosion requirements for long-term retardants, and that probably are suitable for fixed-wing aircraft delivery. All short-term retardants were found to be corrosive (as defined by both uniform and intergranular corrosion tests) to magnesium, and should not be used from helicopters with fixed tanks. Experience suggests that because they do not contain high concentrations of salts, several short-term retardants may be inhibited to yield satisfactory corrosion performance.

Table 5.—Uniform corrosion weight loss test results for short-term retardants exposed for 90 days

	Exposure			
	Total immersion		Partial immersion	
	70° F	120° F	70° F	120° F
	Corrosion rate in mils/year			
Controls[1]				
Distilled water				
2024-T3 aluminum	0.01	0.35	0.09	0.10
4130 steel	1.30	2.13	.65	1.98
Yellow brass	.02	.05	.02	.04
Az-31-B magnesium	.62	.33	.86	.85
Tap water				
2024-T3 aluminum	.72	.04	.16	.05
4130 steel	1.47	1.68	1.29	1.30
Yellow brass	.33	.01	.16	.02
Az-31-B magnesium	1.20	.55	.90	.55
Short-term retardants[2]				
Gelgard				
0.24% 2024-T3 aluminum	.18*			
Tenogum				
0.35% 2024-T3 aluminum	.02*			
Absorbex 2020-SLS				
0.75% 2024-T3 aluminum	.15*			
.66% 2024-T3 aluminum	.02*	.03*	.01*	.01*
.66% 4130 steel	.47	.85	.73	.78
.66% Yellow brass	.12	.80	.14	.24
.66% Az-31-B magnesium	10.3	9.3	4.3	4.6
FT Ac-1				
0.1% 2024-T3 aluminum	.24*			
.5% 2024-T3 aluminum	.01*	.02*	.01*	.01*
.5% 4130 steel	.22	.54	.37	.77
.5% Yellow brass	.05	.02	.03	.02
.5% Az-31-B magnesium	1.5*	.18*	.98*	.18*
Short-Stop (Henkel SGP 502S)				
1.0% 2024-T3 aluminum	.07*			
.75% 2024-T3 aluminum	.30*	.64*	.39*	.49*
.75% 4130 steel	.21	.19	1.1	1.2
.75% Yellow brass	.01	.42	.11	.27
.75% Az-31-B magnesium	2.7*	1.8*	2.5*	2.9*
FT St-Poly				
Colored				
1.5% 2024-T3 aluminum	.02*			
Uncolored				
1.5% 2024-T3 aluminum	.03*			
.66% 2024-T3 aluminum	.03*	.09*	.02*	.16*
.66% 4130 steel	.12	.33	.53	.73
.66% Yellow brass	.01	.04	.01	.03
.66% Az-31-B magnesium	1.7*	1.6*	1.3*	.52*
Fire-Kill II				
1.0% 2024-T3 aluminum	.01*			
.75% 2024-T3 aluminum	.01*	.07*	.01*	.01*
.75% 4130 steel	.08	.26	.29	.89
.75% Yellow brass	.01	.05	.01	.03
.75% Az-31-B magnesium	3.0*	2.3*	2.2*	.18*
Fire-Kill I				
1.0% 2024-T3 aluminum	.01*			

[1] Average of three replications at each exposure on controls.

[2] One coupon tested at each exposure on short-term retardants; * indicates coupons examined for intergranular corrosion.

Table 6.—Results of examinations for intergranular corrosion[1]

Sample	Alloy	Exposure	Observation and/or depth of intergranular attack (inches)
		°F temp/ immersion	
Gelgard	Al	70° total	None observed
Tenogum	Al	70°total	None observed
Absorbex 0.75%	Al	70° total	None observed
.66%	Al	70° total	None observed
	Al	120° total	None observed
	Al	70° partial	None observed
	Al	120° partial	None observed
FT AC-1 1.0%	Al	70° total	None observed
.5%	Al	70° total	None observed
	Al	120° total	None observed
	Al	70° partial	None observed
	Al	120° partial	Intergranular attack - 0.0016 face of panel (trans. and long.)
	Mg	70° total	Intergranular attack - 0.0020 face of panel (trans. long.)
	Mg	120° total	Intergranular attack - 0.0015 face of panel (trans. long.)
	Mg	70° partial	Intergranular attack - 0.0018 face of panel (trans. long.)
	Mg	120° partial	Intergranular attack - 0.0018 face of panel (trans. long.)
Short-Stop 1.0%	Al	70° total	None observed
.75%	Al	70° total	Intergranular attack - 0.0102 long.; 0.0220 trans. edge
	Al	120° total	Intergranular attack - 0.0062 edge attack
	Al	70° partial	Intergranular attack - 0.0400 edge attack
	Al	120° partial	None observed
	Mg	70° total	Intergranular attack - 0.0044 body; 0.0078 edge
	Mg	120° total	Intergranular attack - 0.0032 body; 0.0088 edge
	Mg	70° partial	Intergranular attack - 0.0056 body; 0.0084 edge
	Mg	120° partial	Intergranular attack - 0.0036 body; 0.0032 edge
FT-ST Poly 1.5% c.	Al	70° total	None observed
1.5% u.	Al	70° total	None observed
.66%	Al	70° total	Intergranular attack - 0.0034 body long.; 0.020 edge trans.
	Al	120° total	None observed
	Al	70° partial	Intergranular attack - 0.0191 edge attack
	Al	120° partial	Intergranular attack - 0.0191 edge trans. panel
	Mg	70° total	Intergranular attack - 0.0116 body; 0.0102 edge
	Mg	120° total	Intergranular attack - 0.0032 body; 0.0020 edge
	Mg	70° partial	Intergranular attack - 0.0068 body; 0.0088 edge
	Mg	120° partial	No intergranular attack; general surface attack - 0.0032
Fire-Kill II 1.0%	Al	70° total	None observed
.75%	Al	70° total	None observed
	Al	120° total	None observed
	Al	70° partial	None observed
	Al	120° partial	None observed
	Mg	70°total	Intergranular attack- 0.0040 body; 0.0044 edge
	Mg	120° total	Intergranular attack - 0.0022 body; 0.0036 edge
	Mg	70° partial	Intergranular attack - 0.0028 body; 0.0034 edge
	Mg	120° partial	Intergranular attack - 0.0028 body; 0.0038 edge
Fire-Kill I 1.0%	Al	70° total	None observed

[1] long. = longitudinal; trans. = transverse; c = colored; u = uncolored.

It is recommended that efforts be initiated to develop corrosion inhibitors for short-term retardants or to develop new formulations that will meet established corrosion requirements. Formulations that caused intergranular corrosion on aluminum should not be applied from fixed-wing aircraft, and formulations causing intergranular corrosion on magnesium should not be applied from helicopters utilizing fixed tanks (or other systems where released retardant contaminates the aircraft).

REFERENCES

Bradford, S. A. Corrosion of aircraft metals in fire retardants. Edmonton, Alberta, Canada: Canadian Forestry Service, Department of the Environment, Northern Forest Research Centre; 1973. 61 p.

Bradford, S. A. Corrosion of steels in fire retardants. Edmonton, Alberta, Canada: Canadian Forestry Service, Department of the Environment, Northern Forest Research Centre; 1974. 90 p.

Davis, J. B.; Phillips, C. B. Corrosion of air tankers by fire retardants. A report for California Air Attack Coordinating Committee. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Equipment Development Center; 1965. 38 p.

Gehring, G. A., Jr. An investigation of fire retardant-caused corrosion. Final report, Contract 26-3250, Ocean City Research Corp., Ocean City, NJ. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 121 p.

Gehring, G. A., Jr. Laboratory studies of fire retardant corrosion. Final report, Contract 26-3250, Ocean City Research Corp., Ocean City, NJ. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978. 54 p.

Gehring, G. A., Jr. An investigation of fire retardant-caused corrosion (extended study). Final report, Contract 40-0353-7-799, Ocean City Research Corp., Ocean City, NJ. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 56 p.

U.S. Department of Agriculture, Forest Service. Corrosion to airtankers from fire retardant chemicals. In: Equip Tips. Arcadia, CA: Equipment Development Center; 1964 December. Unpaged.

U.S. Department of Agriculture, Forest Service. Specification for long-term retardant, forest fire aircraft or ground application. Interim Spec. 5100-00304. San Dimas, CA: San Dimas Equipment Development Center; 1982. 25 p.

George, Charles W.; Johnson, Cecilia W. Corrosivity of short-term fire retardants. Research Paper INT–329. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 8 p.

Aluminum, brass, iron, and magnesium alloys were totally and partially immersed in short-term forest fire retardant solutions at 70° and 120° F, and then examined after 90 days for uniform and intergranular corrosion. Short-term retardants generally caused less uniform corrosion but more intergranular corrosion than long-term retardants, particularly to magnesium. New inhibitor packages should be developed. Two of the formulations tested were recommended for use from fixed-wing aircraft; however, due to severe magnesium corrosion none should be used from helicopters using fixed tank delivery systems.

KEYWORDS: corrosivity, fire retardants, short-term, long-term, procedures, exposure, uniform corrosion, intergranular corrosion, inhibitors, fixed-wing, helicopters, aircraft, alloys

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

? U.S. GOVERNMENT PRINTING OFFICE: 1984—776-032/1073 REGION NO. 8